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The contribution of ISO 14067 to the evolution of global greenhouse gas standards – a review

Abstract

Due to the increasing recognition of global climate change, the building and construction industry is under pressure to reduce carbon emissions. A central issue in striving towards reduced carbon emissions is the need for a practicable and meaningful yardstick for assessing and communicating greenhouse gas (GHG) results. ISO 14067 was published by the International Organization for Standardization in May 2013. By providing specific requirements in the life cycle assessment (LCA) approach, the standard clarifies the GHG assessment in the aspects of choosing system boundaries and simulating use and end-of-life phases when quantifying carbon footprint of products (CFPs). More importantly, the standard, for the first time, provides step-to-step guidance and standardized template for communicating CFPs in the form of CFP external communication report, CFP performance tracking report, CFP declaration and CFP label. ISO 14067 therefore makes a valuable contribution to GHG quantification and transparent communication and comparison of CFPs. In addition, as cradle-to-grave should be used as the system boundary if use and end-of-life phases can be simulated, ISO 14067 will hopefully promote the development and implementation of simulation technologies, with Building Information Modelling (BIM) in particular, in the building and construction industry.

Keywords: Carbon footprint; GHG quantification; GHG communication; ISO 14067.

1. Introduction

Climate change has emerged as one of the most pressing environmental issues in recent years. It can cause big threats to future development, including raising sea level and causing natural disasters. According to the Intergovernmental Panel on Climate Change (2007), eleven of the last twelve years (1995-2006) ranked among the twelve warmest years in the instrumental record of global surface temperature since 1850. Global average sea level has risen since 1960 at an average rate of 1.8mm/year and since 1993 at 3.1mm/year, which has considerable impact on future development (Intergovernmental Panel on Climate Change, 2007). Billions of people are exposed to natural disaster risks, including weather-related disasters that take lives, damage infrastructure and natural resources, and disrupt economic activities (Pelling et al., 2004).

There is broad consensus that global climate change is caused by an increase in GHG emissions from both natural and man-made sources (Environment Agency, 2005). If actions were not taken to reduce greenhouse gas (GHG) emissions, the overall costs and risks of climate change would be equivalent to losing at least 5% of global GDP per year, now and forever (Stern, 2007). In particular, human activity is believed to be the most significant source of emissions, which is mainly caused by fossil fuel consumption. The quantification of human activity on global GHG emissions level calls for a systematic assessment method. There is also an increasing desire from retailers and other supply chain organizations to better understand, and in some cases, communicate a consumption-based perspective of the carbon footprint of products (Carbon Trust, 2006).

There are a number of attempts to develop a globally recognized mechanism to assessment the carbon footprint of products (CFPs) across their life cycle. Publicly Available Specification (PAS) 2050 was published by the British Standards Institution in Oct 2008. It includes detailed requirements for the assessment of GHG emissions arising from goods and services (Sinden, 2009). World Resources Institute (WRI)/World Business Council for Sustainable Development (WBCSD) developed the greenhouse gas protocol for product accounting and reporting standard (hereafter referred to as WRI/WBCSD: The GHG Protocol) in 2001. WRI/WBCSD: The GHG Protocol was revised and published in 2011 to provide a general framework to support GHG quantification and reporting for many different types of products (WRI/WBCSD, 2011). Although PAS2050 and WRI/WBCSD: The GHG Protocol have similar standards and are unlikely to result in significant differences in measurement outcomes, the industry needs one uniform and globally recognized standard for assessing and communicating GHG results at a practical level. ISO 14067: Carbon footprint of products – requirements and guidelines for quantification and communication was published in May 2013. It brings significant changes to current carbon labelling schemes in terms of allowing transparent communication of GHG results and can be used as the uniform standard for assessing and communicating GHG results. While there are many similarities among the three internationally recognized GHG standards, ISO 14067 clarifies and details the assessment method by providing some specific requirements on the selection of system boundary and simulating use and end-of-life phases. More importantly, it proposes a standardized communication program based on which GHG results can be transparently communicated with customers to allow them to make informed decisions.

This paper therefore aims to examine how ISO 14067 assesses and communicates GHG results. It is believed that the findings from this study will help understand the contribution of ISO 14067 to the evolution of global GHG standards and its impact on the building and construction industry.

2. The Development of ISO 14067

The standard was proposed in the first ISO/TC (Technical Committee) 207 / WG (Working Group) 2 meeting in April 2008. It was developed by over 100 experts from more than 30 countries, including developing countries such as China, Argentina, Indonesia, etc., and received a large number of comments from international involvement. According to ISO (2009), the first draft of ISO 14067 received 578 comments on *Part 1: Quantification* and 184 comments on *Part 2: Communication*. However, due to the objection raised by some countries, ISO 14067 was published as a Technical Specification rather than an internationally recognized standard in May 2013. The Technical Specification will be reviewed by May 2016 to determine whether it will be revised, withdrawn or published as an international standard.

ISO 14067 specifies principles, requirements and guidelines for the quantification and communication of the carbon footprint of products (CFPs), covering both goods and services, based on GHG emissions and removals over the life cycle of a product (ISO 14067, 2013). The standard was developed based on previous international standards on environmental labelling and environmental management, including:

- ISO 14020: Environmental labels and declarations – general principles
- ISO 14024: Environmental labels and declarations – Type I environmental labelling – principles and procedures
- ISO 14025: Environmental labels and declarations – Type III environmental declarations – principles and procedures
- ISO 14040: Environmental management – Life cycle assessment – principles and framework

- ISO 14044: Environmental management – Life cycle assessment – requirements and guidelines

The standard has two main objectives. It aims to standardize the quantification principles and procedures when assessing CFPs. A complete CFP study in ISO 14067 should include a CFP quantification process, a CFP study report based on the results from the CFP quantification and a critical review based on ISO 14044. It should be noted that the critical review in ISO 14067 is different from third party verification. A critical review process ensures that (ISO 14044, 2006):

- the methods used to carry out the LCA are consistent with the International Standard;
- the methods used to carry out the LCA are scientifically and technically valid;
- the data used are appropriate and reasonable in relation to the goal of the study;
- the interpretations reflect the limitations identified and the goal of the study; and
- the study report is transparent and consistent.

Such review is only needed in the CFP quantification stage while third party verification, which is the confirmation , through provision of evidence, that specific requirements related to the CFP study and its communication has been fulfilled, should be provided if the CFP study is intended to be publicly available (ISO 14067, 2013). The third party verification can also be replaced by a CFP disclosure report.

In the communication stage, ISO 14067 standardize the processes and reports that should be provided if the CFP study is intended to be publicly available. The communication can take the form of a CFP external communication report, a CFP performance tracking report, a CFP label or a CFP declaration. A standardized format of each communication type is also provided in ISO 14067. The processes and reports will make sure that reliable comparisons of different CFPs can be made.

3. The contribution of ISO 14067

In order to achieve the above two objectives, it must reduce the ambiguity that is not addressed by PAS 2050 and WRI/WBCSD: The GHG Protocol.

3.1 Assessment Practices

3.1.1 Assessment principles

Similar to PAS 2050 and WRI/WBCSD: The GHG Protocol, ISO 14067 shares a set of principles when assessing GHG emissions, which are *relevance, completeness, consistency, accuracy* and *transparency*. Other than these assessment principles, ISO 14067 proposes a few new principles, including:

- *Coherence*. Coherence is about selecting recognized assessment guidelines to ensure comparability between different materials within the same category, e.g. cementitious materials.
- *Avoidance of double-counting*. This principle should be considered in situations where supplier/generator-specific emission factors for electricity are used (ISO 14067, 2013, p.25).
- *Participation*. ISO 14067 encourages the involvement of interested parties in the communication programs.
- *Fairness*. ISO 14067 is the assessment and communication of one single category of environmental impact – climate change. Quantified carbon emissions and reductions in GHG emissions should be treated separately.

One major difference between ISO 14067 and PAS 050 is that ISO 14067 focuses on the communication of the results to third parties as well. The newly added principles will contribute to the transparent communication and comparison of GHG results. For example, as the CFPs from isolated life cycle stages cannot be made publicly available in the form of carbon label, suppliers and subcontractors that offer services in life cycle stages that are not interconnected are encouraged to participate in the CFP study if they intend to be accredited in the form of carbon label.

3.1.2 System boundaries

System boundaries define the life cycle stages that should be included in LCA studies. PAS 2050 and WRI/WBCSD use cradle-to-grave and cradle-to-gate as the system boundaries. In ISO 14067, four system boundary options are proposed:

- Cradle-to-grave: a cradle-to-grave quantification includes the emissions and removals arising from the full life cycle of the product (British Standard Institute, 2011). The cradle-to-grave system boundary is preferred in ISO 14067 and must be used when use and end-of-life phases can be adequately simulated.
- Cradle-to-gate: a cradle-to-gate quantification includes the emissions and removals arising up to the point at which the product leaves the organization undertaking the assessment for transfer to another part (British Standard Institute, 2011).
- Gate-to-gate: a gate-to-gate quantification includes the emissions and removals arising within different organizations in the supply chain. This can be adopted when emissions from cradle to the receiving gate is difficult to obtain.
- Partial CFP: a partial CFP includes the emissions and removals from a restricted number of isolated stages.

The introduction of gate-to-gate and partial CFP as system boundaries addresses the issues when the extraction and manufacture of raw materials are not available in common LCA databases or when interconnected LCA data is not available. In addition, ISO 14067 proposes a process of refining the system boundary through sensitivity analysis. If life cycle stages are excluded from the CFP study due to their relatively low importance, sensitivity analysis should be conducted to validate and support the decisions and the results of the sensitivity analysis should be documented in the CFP report. The strategies proposed by ISO 14067 rule out the possibility of data manipulation in selecting system boundaries. Manufacturers will not be able to exclude life cycle stages that they claim to have limited significance without the support of appropriate sensitivity analysis.

3.1.3 Function unit

The function unit in ISO 14067 can be a product or a service. The CFP results can be reported on a self-selected product unit basis, e.g. one item of product. The results can also be expressed in terms of services provided. For example, in the construction industry, natural light can be provided for illumination through the use of French doors and windows instead of light bulbs, thus, the functional unit can be expressed in terms of luminous flux per unit area. The results will therefore be documented in mass of CO_2e per luminous flux per unit area.

3.1.4 Unit of measurement

The unit of measurement in ISO 14067 and other GHG standards is carbon dioxide equivalent (CO_2e). Other GHG emissions, such as CH_4, SF_6, Hydrofluorcarbons (HFCs), Perfluorocarbons (PFCs) and Biomass CO_2 emissions should also be included in the quantification procedure because these GHG emissions have much higher global warming potential than carbon emissions. For example, methane has a global warming potential coefficient of 25, which means 1 kg of methane is equivalent to 25kg CO2 in terms of its global warming potential (British Standards Institution, 2011, p.10). However, carbon dioxide is still used as unit of measurement in a significant number of studies and carbon labelling programmes. For example, the Singapore Green Labelling Scheme (Singapore) and CarbonCounted (Canada) use carbon dioxide as the standard unit of measurement. In accordance with PAS 2050 and WRI/WBCSD: The GHG Protocol, ISO 14067 mandates the use of carbon dioxide equivalent as the unit of measurement. Although carbon dioxide can be used if there are minimal amount of other GHG emissions generated in the product life cycle, such practice will not be accredited by all of the three globally recognized GHG standards.

3.1.5 Use phase and end-of-life phase

There was a considerable debate over the treatment of emissions generated from the use phase of the product and whether this should be included or excluded (Sinden, 2009). The main reason for excluding use phase is the large number of uncertainties regarding how products/materials will be used in this stage due to varied user behaviours in terms of activities such as maintenance and replacements. However, the CFP would not be complete to support informed decisions when use phase and end-of-life phase may have a significant impact on the CFP. For example, 25% of the CO_2 emitted in the calcination process, which is one major source of carbon emissions in the cement industry, will be reabsorbed in concrete by 100 years in Denmark, Norway and Sweden (Kjellsen et al., 2005). Following the cradle-to-gate system boundary, the GHG emissions of concrete products are strongly overestimated (Kjellsen et al., 2005). Similarly, various studies have found that the effect of carbonation on the net CO_2 emissions related to concrete in its life cycle, which is highly influenced by the way concrete is handled after demolition, can be significant (e.g. Pade and Guimaraes, 2007; Collins, 2010). A true CFP quantification should include the life cycle of the product, especially when the simulation of the use phase and final disposal of the products has been well investigated. To address the issue, ISO 14067 offers step-by-step guidance to determine the use stage and use profile, which describes the assumptions underlying the assessment of emissions from the use stage. The guidance can be summarized into a three step process, which is:

- Step 1 – aim for verifiable service life information that represents the actual usage pattern.
- Step 2 – use simulations to model the use profile based on published technical information, such as published international standards, published national guidelines, published industry guidelines and documented usage patterns in the selected market (in order of preference), if step 1 cannot be completed.
- Step 3 – use simulations to model the use profile based on the manufacture's recommendation for proper use, if step 2 cannot be completed.

3.1.6 CFP study report

The purpose of the CFP study report is to document the results of the quantification procedure and to prepare for communication if the results are intended to be publicly available. PAS 2050 does not provide requirements on what should be included in the summary report of the quantification phase. ISO 14067 proposes a standard format which offers great clarity for the follow-up communication programme. In addition to basic assessment procedures (system boundary, functional unit, relevant assumptions, result of the life cycle study, etc.), the CFP study report should also include:

1. Specific GHG emissions and removals, e.g. the generation of electricity and direct land use change (dLUC).
2. A sensitivity check of the specific GHG emissions and removals.
3. Absolute and relative contribution of each life cycle stage to the overall GHG emissions and removals. A few ratio indicators can therefore be calculated and provided in the communication program. The use of ratio indicators will be discussed in the communication practices of ISO 14067.

4. Descriptions of the use profile and end-of-life scenarios (optional) and evidence of compliance regarding comparisons (optional).

In summary, Table 1 shows the comparison of PAS 2050, ISO 14067 and WRI/WBCSD: The GHG Protocol. As can be seen from Table 1, ISO 14067 makes a significant contribution to GHG quantification in terms of refining system boundaries through the use of sensitivity analysis and mandating the use of cradle-to-grave as system boundary if the products' use and end-of-life phases can be adequately simulated and the results are intended to be publicly available.

<Insert Table 1 here>

3.2 Communication Practices

The aim of GHG assessment is to allow customers to make informed decisions. However, this area is not included in the scope of PAS 2050 and is only briefly discussed in the WRI/WBCSD: The GHG Protocol. Contrary to PAS 2050, ISO 14067 provides guidance for manufacturers and companies deciding to communicate the CFP results, which can take the form of a CFP label, a CFP external communication report, a CFP performance tracking report, or a CFP declaration. No matter which form of communication is chosen, the CFP communication should either be verified by a third party or be supported by a CFP disclosure report. The verification is intended to cover the whole CFP program while the critical review only to cover CFP quantification. The standard encourages the use of third part verification to ensure conformity. If third party verification cannot be achieved, self-verification in the form of CFP disclosure report must be provided. Although self-verification is also available in PAS2050, ISO 14067 provides a standardized template for CFP disclosure report, which includes the CFP study report (critical reviewed), contact information, product information, type of CFP (partial or full), CFP-Product Category Rule (PCR), etc.

3.2.1 CFP label

CFP communication can take the form of a CFP label, which is often referred to as carbon label nowadays, aiming for direct consumer communication. Under the three-category classification recommended by Trusty (2001), carbon labels belong to Level 1 classification which is used a product comparison tool. Under the three-category classification recommended by ISO 14025 (2006), carbon label is a single-issue Type III environmental declarations which present the carbon performance of a product to enable objective comparisons between products fulfilling the same functions. Many carbon labels, such as the Singapore Green Label Scheme (SGLS), CarbonFree (the U.S.), CO_2 Measured Label (UK) and CarbonCounted (Canada), have been developed to assist customers to choose carbon neutral products. The GHG information is aggregated into a single score in most carbon labels. The ISO technical committee finds that a single number can create confusion and sufficient information should be provided to enable customers to understand the specific components in the CPF study (ISO 14067, 2013). For the first time, ISO 14067 provides guidance and regulation on the use of carbon labels. If the CFP results are intended to be publicly available in the form of a carbon label, the standard, including the reports that should be included, can be seen in Table 2.

<Insert Table 2 here>

As can be seen from Table 2, if a carbon labelling program is intended to be publicly available and compliant with ISO 14067, three reports, including communication program, product category rule and 3rd party verification/disclosure report should be provided. This is in accordance with previous findings that an aggregated single score can suppress other information when evaluating the products' environmental quality, although it can offer the customers an intuitive explanation of the products' environmental compatibility (Wu and Feng, 2012).

Compared with PAS 2050 and WRI/WBCSD: The GHG Protocol, one important change of carbon labelling practice in ISO 14067 is related to the use of CFP label to communicate cradle-to-gate CFP and partial CFP. Cradle-to-gate can be used as the system boundary of CFP study only if (ISO 14067, 2013):

- information on specific stages (e.g. the use and end-of-life stages of the product) is not available and reasonable scenarios cannot be modelled; or
- there are stages that are insignificant for the GHG emissions and removals of the product.

This will affect some carbon labelling schemes that use cradle-to-gate as the system boundary. For example, the SGLS uses cradle-to-gate as the system boundary to assess the carbon emissions of cementitious materials (e.g. precast concrete). If the Singapore Environment Council, the founder of the SGLS, wishes to continue to use cradle-to-gate as the system boundary, the council should prove evidence that the operational and demolition stage of precast concrete have a minimal impact on GHG emissions. This cannot be achieved because various studies have found that the effect of carbonation on the net CO_2 emissions related to concrete in its life cycle, which is highly influenced by the way concrete is handled after demolition, can be significant (e.g. Pade and Guimaraes, 2007; Collins, 2010). These life stages can also be appropriately modelled as evidenced by these studies. Therefore, under the requirements of using CFP label proposed by ISO 14067, the Singapore Environment Council will have to change the system boundary to cradle-to-grave for some construction materials, such as cementitious materials, because neither of the two above exclusions can be met.

ISO 14067 also prohibits the use of CFP label when communicating a partial CFP, which includes the emissions and removals from a restricted number of isolated stages. This can prevent suppliers and subcontractors intending to be accredited with a carbon label for their services. For example, a subcontractor offers the services of transporting raw materials from extraction to manufacturing plants as well as transporting finished products from manufacturing plants to retail centres. As the two transportation stages are isolate life cycle stages, the subcontractor will not be able to communicate the GHG results of the transportation service under the new ISO14067, although the service can still be quantified by the standard. In the function of delivering products, the selected function unit may be expressed in terms of GHG emissions per tonne per km of transported product.

3.2.2 CFP external communication report and CFP performance tracking report

CFP external communication report and CFP performance tracking report aim at business to business communication instead of direct consumer communication. The design of the two forms is therefore very concise in ISO 14067 with the inclusion of third part verification or CFP disclosure report. While the CFP external communication report aims at external communication, the CFP performance tracking report aims at internal benchmarking in the same organization. The provision of benchmarking process is in accordance with previous research and practices. For example, WRI/WBCSD: The GHG Protocol suggests the use of performance measurement against external and internal benchmarks to represent the eco-efficiency (WRI/WBCSD, 2010). Wu and Feng (2012) proposed that a lean score, which is obtained from a benchmarking process with the best production scenario, can be used to enhance the credibility and increase the comprehensiveness of the carbon label information in terms of showing the efficiency of the production process. Verfaillie and Bidwell (2000) suggested the use of eco-efficiency ratios when reporting the results of environmental assessments. A comparison of the two reports can be seen in Table 3.

<Insert Table 3 here>

3.2.3 CFP declaration

The communication of CFP results can also take the form of CFP declaration, which is developed under ISO 14025. As the declaration content is very similar to the CFP disclosure report, it will not be discussed separately.

3.2.4 Comparing the carbon footprints of different products

Another significant contribution of ISO 14067 is, for the first time, providing guidance on the comparison of carbon footprint of different products. Comparisons can only be made if the CFPs to be compared follow identical CFP quantification and communication requirements (ISO 14067, 2013). This can help to reduce ambiguity in a few carbon labelling programmes. For example, in CarbonFree (the U.S.), GHG emissions from six major processes (i.e. extraction of raw materials, transportation of raw materials, manufacturing processes, transportation to end users, product use and disposal) should be mandatorily included in the calculation process. However, there are a few emission sources that can be voluntarily included in the calculation process. These voluntary inclusions can be emissions from capital facilities, such as offices and manufacturing of physical infrastructure. Carbon emissions generated from product use can also be excluded if written consent is obtained from CarbonFund. These voluntary inclusions make the coherence principle difficult to be complied with. As system boundaries across different products may vary significantly if self-assessment is allowed, comparing CFPs of different products are not allowed if the system boundaries vary under ISO 14067. Even the slightest change in quantification and communication requirements can prevent comparisons.

Even when assessed using identical CFP quantification and communication requirements, products with lower CFP does not mean that they have a superior environmental performance than products with higher CFP. Climate change is only one of a variety of environmental impacts from the products’ life cycle. Focusing on climate change can suppress other environmental impacts. In some cases, action to minimise a single environmental impact can result in greater impacts arising from other environmental aspects. For example, while many landfill options can be used to reduce waste, these options will lead to high impact in terms of carbon emissions (Barton et al., 2008).

Partial CFP, under ISO 14067, cannot be compared unless the omitted life cycle stages are identical for the products compared. Comparisons can only be made if all subcontractors are involved in delivering the same product in the same transportation stages, e.g. transportation from extraction sites to manufacturing factories and from manufacturing factories to retail places using the example explained earlier in the paper. It should however be noted that such comparison cannot be provided in the form of CPF label. The ratio indicators provided in the WRI/WBCSD: The GHG Protocol cannot therefore be used in the carbon label for logistics companies.

Extreme care should be taken when using ratio indicators to compare similar products. Ratio indicators are proposed in WRI/WBCSD: The GHG Protocol and many other studies to present the eco-efficiency of the products (e.g. WRI/WBCSD, 2010; Wu and Feng, 2012; Verfaillie and Bidwell, 2000). Ratio indicators are related to the reporting of the products' GHG emissions normalized by some product metrics. Some common type of ratio indicators can be seen in Table 4. While some ratio indicators, e.g. percentage, can still be used as a method of comparison because these ratio indicators use the same physical unit in the numerator and the denominator, some other ratio indicators, e.g. intensity ratio, may not be valid under ISO 14067 because they may be calculated on different system boundaries or on non-identical product systems.

<Insert Table 4 here>

4. Discussions

The building and construction sector is one of the largest sources of carbon emissions. The manufacturing process of building materials (e.g. cement and steel) and chemicals have considerable impact on CO_2 emissions level (Worrell et al., 2011a). For example, the cement sector alone accounts for 5% of global man-made CO2 emissions (Worell et al., 2001b). Due to the rising recognition of global climate change, many sectors, with the building and construction sector no exception, are under pressure to reduce carbon emissions. A central issue in striving towards reduced carbon emissions is the need for a practicable and meaningful yardstick for assessing and communicating GHG results (Crawley and Aho, 1999).

The assessment principles of previous GHG standards are based on the life cycle assessment method originated from ISO 14040 and ISO 14044, which provide flexibility for organizations and countries to develop their own assessment guidelines. However, as Sinden (2009) pointed out, while ISO 14040 and ISO 14044 provide sufficient flexibility to allow bespoke approaches to suit the requirements of each individual study, it is this flexibility that can limit the applicability of the standards and the credibility of the environmental information. Wu et al. (2013) compared three carbon labels from Singapore, the U.S., and UK and found that although these carbon labels are based on the LCA method, comparisons cannot be made because many transparency issues, such as system boundary, unit of measurement and accredited evaluation, vary significantly across the these three carbon labels. Koning et al. (2010) provided an example showing how increasing the discretion of choosing system boundaries in LCA studies can result in misleading results. Manufacturers can manipulate data in the operational stage to create “low carbon” products. Flexibility in choosing individual system boundary can harm the coherence and consistency principle. The problem highlights the importance of developing one uniform and globally recognized GHG quantification standard. The timely ISO 14067 sets up many assessment standards to avoid confusion. For example, partial CFP can be used when the extraction and manufacture of raw materials are not available in common LCA databases or when interconnected LCA data is not available. However, it cannot be publicly available in the form of a CFP label, which aims for direct communication with consumers who, at the moment, may not obtain adequate GHG awareness. In a survey investigating the awareness of carbon labelling conducted by Upham et al. (2011, p.352), respondents were perplexed by the measurements involved, with the following typical resultant comments:

> "It's difficult. I've no idea what 260 g of carbon looks like. I'm sure it's better [than the comparatively higher carbon product] but I have no idea what the impact of 260 g is like. I have no idea".

The need for a unified assessment standard is also supported by the International Energy Agency (IEA). IEA (2001) argued that the calculation could be very misleading if evaluators do not use one single homogenous set of data or boundary. For example, the carbonation of concrete in the use phase can cause the life cycle GHG emissions to reduce by 5.5% (Kikuchi and Kuroda, 2011). Salazar and Meil (2009) stated that due to the post-use energy recovery, wood materials have a high carbon benefit that should not be overlooked. As such, a common boundary definition is needed and sector-relevant benchmark and performance indicators are necessary to solve the problems of boundaries (IEA, 2008). According to Wu et al. (2014), the unified assessment principles proposed in ISO 14067 is referred to as product category rules, which includes the life cycle stages to be included, the parameters to be covered and the way in which the parameters shall be collated and documented, for each type of material. Although the current assessment standards target the production process only, IEA (2007) and ISO 14067 (2013) agree that products and manufactured materials should be part of a society-wide flow, which also includes application, disposal and treatment for recycling. As manufacturers specialised in production may have limited control over the later stages of the product's life cycle, such as the use and end-of-life phases, policy and regulations play a very important role in standardizing how these later stages can be included in the life cycle assessment (IEA, 2007).

It should also be noted that the aim of GHG quantification is to provide credible environmental information to allow customers to make informed decisions. Transparent communication is therefore important because statistics have shown that a small change in consumer consumption may have important effects on domestic and global emissions (Cohen and Vandenbergh, 2012). Reducing the consumption of construction materials with high embodied carbon can help reduce domestic and international GHG emissions, especially for countries like Singapore which rely heavily on the import of construction materials. Research in carbon labelling has shifted to how environmental assessment results can be transparently communicated with customers so that informed decisions can be made. Cole (1998) argued that the ability to make informed decisions based on the outcome of the assessment is more critical. As such, in recent years, many studies have been conducted on using benchmarking to communicate the GHG results to customers. For example, Zhao et al. (2012) proposed the use of carbon emissions intensity ratio, which is normalized by the annual national greenhouse gas emission per gross domestic product, to represent the level of carbon emissions intensity. Similarly, WRI/WBCSD (2011) proposed the use of category ratio to establish a relationship between data from different categories and productivity/efficiency ratio to express the value of a business divided by its GHG impact. Ng et al. (2012) suggested that tiered rating/grading can be used to label products in different grades based on their performance to support decision making. The tiered rating/grading has been used in the new Hong Kong Carbon Labelling Scheme, which was officially launched in December 2013 (Construction Industry Council, 2013). This is extremely important when current life cycle assessment results are predominantly used by professional groups rather than customers. Environmental consideration, compared to quality, brand and specific needs, was not a top priority when selecting products for customers (Upham et al., 2011). This problem cannot be amplified by providing confusing and misleading information.

The publication of ISO 14067 is therefore timely as it sets up standards when communicating the GHG results in the form of carbon labels. Three mandatory reports must be provided along with the carbon label. In addition, carbon labels proposed in ISO 14067 do not preclude the use of ratio indicators, as suggested by WRI/WBCSD: The GHG Protocol, and other innovative communication practices. ISO 14067 provides an excellent platform on which many relevant carbon labelling practices and principles can be further tested and developed. It is expected that with the contribution of transparent and comparable carbon labels, customers will prefer construction materials with low embodied carbon or relatively strong ratio indicators.

ISO 14067 provides opportunities for the building and construction industry to effectively address global climate change. Manufacturers and contractors are not allowed to use cradle-to-gate as the system boundary when the operational and end-of-life phases of the materials/products have been well established or simulated. The simulations of operational and end-of-life phases have been conducted for a variety of building materials/products, such as concrete, steel and precast concrete. The proposition of using cradle-to-grave in ISO 14067 will promote the use of Building Information Modelling (BIM) or other simulation technologies to identify the GHG emissions of the materials/products in their true life cycle. It will also promote the development of international, national and industrial standards that specify guidance and requirements on scenarios for the operational and end-of-life phases of the products. In addition, if building materials/products are accredited by ISO 14067, comparison based on the CFP of different products can be made. ISO 14067 can support building and construction companies that provide comparison, interpretation and communication services relating to GHG emissions in the industry.

Carbon label can offer customers an intuitive explanation of products' environmental compatibility in the category of global climate change in a simpler way compared to emissions report and emissions reduction plan. However, as partial CFP cannot be communicated in the form of carbon label under ISO 14067, this can create difficulty for companies (e.g. logistics companies) that offer services in life cycle stages that are not interconnected. Although GHG emissions from these isolated life cycle stages can still be communicated in the form of external communication report and performance tracking report, it will require customers to have adequate environmental knowledge to understand the report. To address the issue, companies that offer services in life cycle stages that are not interconnected can work closely with manufacturers and contractors to be actively involved in the CFP programme developed for a specific building material/product. As ISO 14067 does not preclude the use of ratio indicators in CFP labels, GHG emissions from isolated life cycle stages can be presented through the use of ratio indicators, allowing these companies to be partially branded in the form of CFP label. In this way, ISO 14067 embraces the participation principle by creating an open and participatory process with interested parties.

5. Conclusions

The aim of GHG quantification is to provide useful, credible and transparent information for customers to make informed decisions. However, the flexibility in previous LCA approaches limits the applicability of GHG quantification and the credibility of the CFPs. The publication of ISO 14067 is timely and shows the evolution of international GHG standard in the aspect of GHG quantification by restricting the use of system boundaries other than cradle-to-grave if the use and end-of-life phases of the products can be simulated. It also provides a standardized template for reporting CFP studies so that transparent communication can be made if these studies are to be made publicly available.

ISO 14067, for the first time, provides guidance on the transparent communication and comparison of CFP studies, especially in the form of CFP labels. It states that even the slightest change in quantification requirements can prevent comparisons. The guidance will therefore be useful to improve carbon labelling schemes in the building and construction industry, such as the SGLS, CarbonFree and CarbonCounted, by ensuring consistency and coherence when assessing CFPs. The proposition of using cradle-to-grave in ISO 14067 will promote the use of Building Information Modelling (BIM) or other simulation technologies to identify carbon footprint in the products' true life cycle. In addition, as partial CFPs will not be accredited in the form of carbon labels, suppliers and other subcontractors that offer services in life cycle stages that are not interconnected will have to participate in the CFP study if they intend to be accredited in the form of carbon label. This creates an open and participatory process with interested parties. The development of ISO 14067 shows the evolution of international GHG standards towards how the results of assessments can be transparently communicated with end users and the building and construction industry should be fully prepared to embrace the new changes.

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